Airborne aerosol in-situ observations of volcanic ash layers of the Eyjafjallajökull volcano in April & May, 2010, over central Europe

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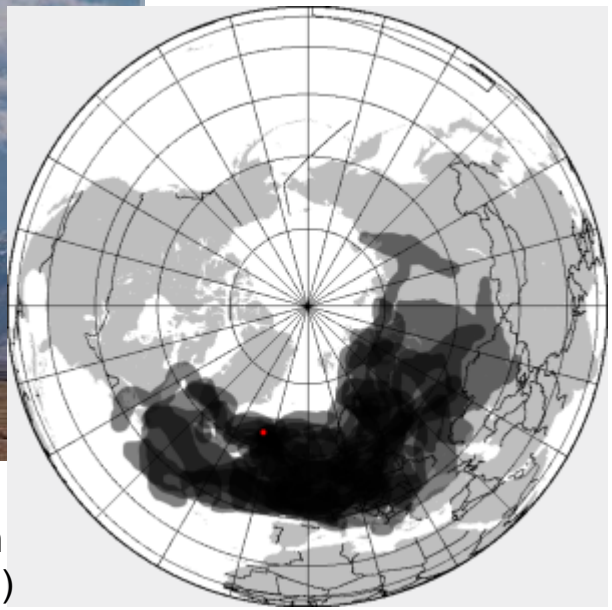
DLR Oberpfaffenhofen, Institut für Physik der Atmosphäre, Germany

Eyjafjallajökull .... pronounced ['ɛɪja,fjatl̥a.jœkʏtl̥]

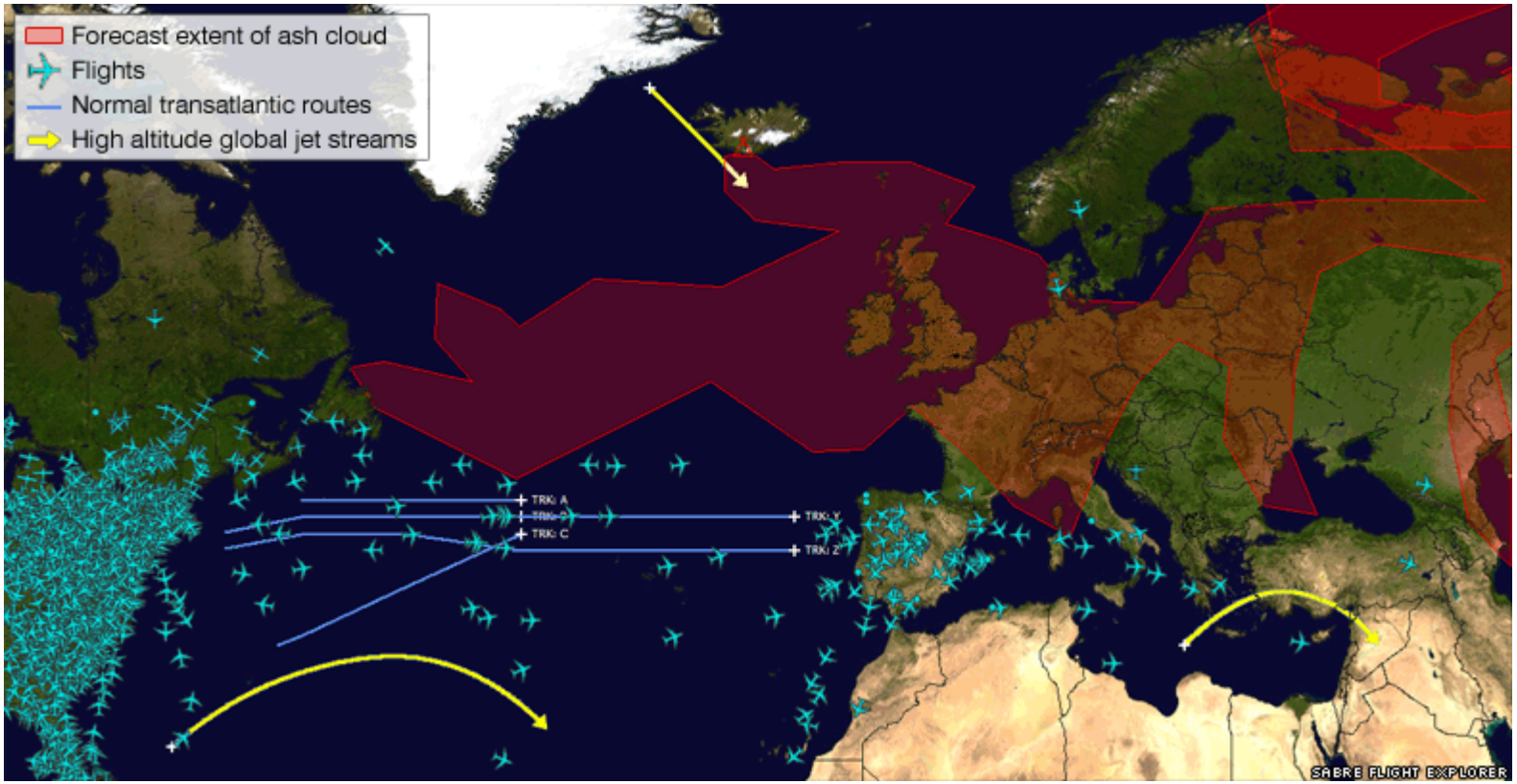
Eruption occurred (below ice) on early morning of 14 April 2010

http://en.wikipedia.org/wiki/Air_travel_disruption_after_the_2010_Eyjafjallajökull_eruption



Distribution of ash
(composite map of first 10 days)

Mid-European airspace closed for several days (here air traffic situation at April 19, 2010)



http://www.radarvirtuel.com/
taken from BBC: Iceland volcano in maps

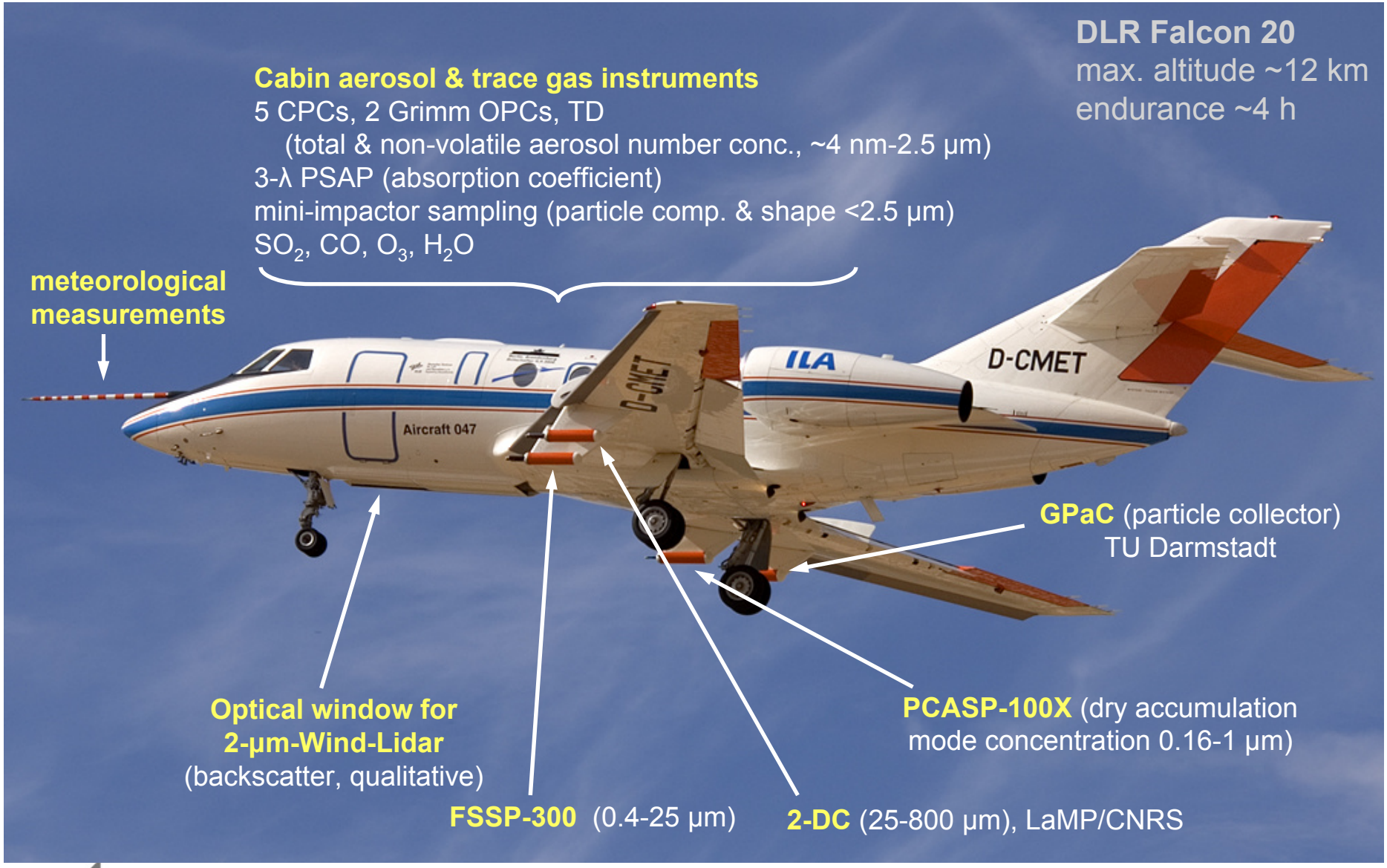
First flight of DLR-Falcon on this day (with special permission)

Operational & scientific questions

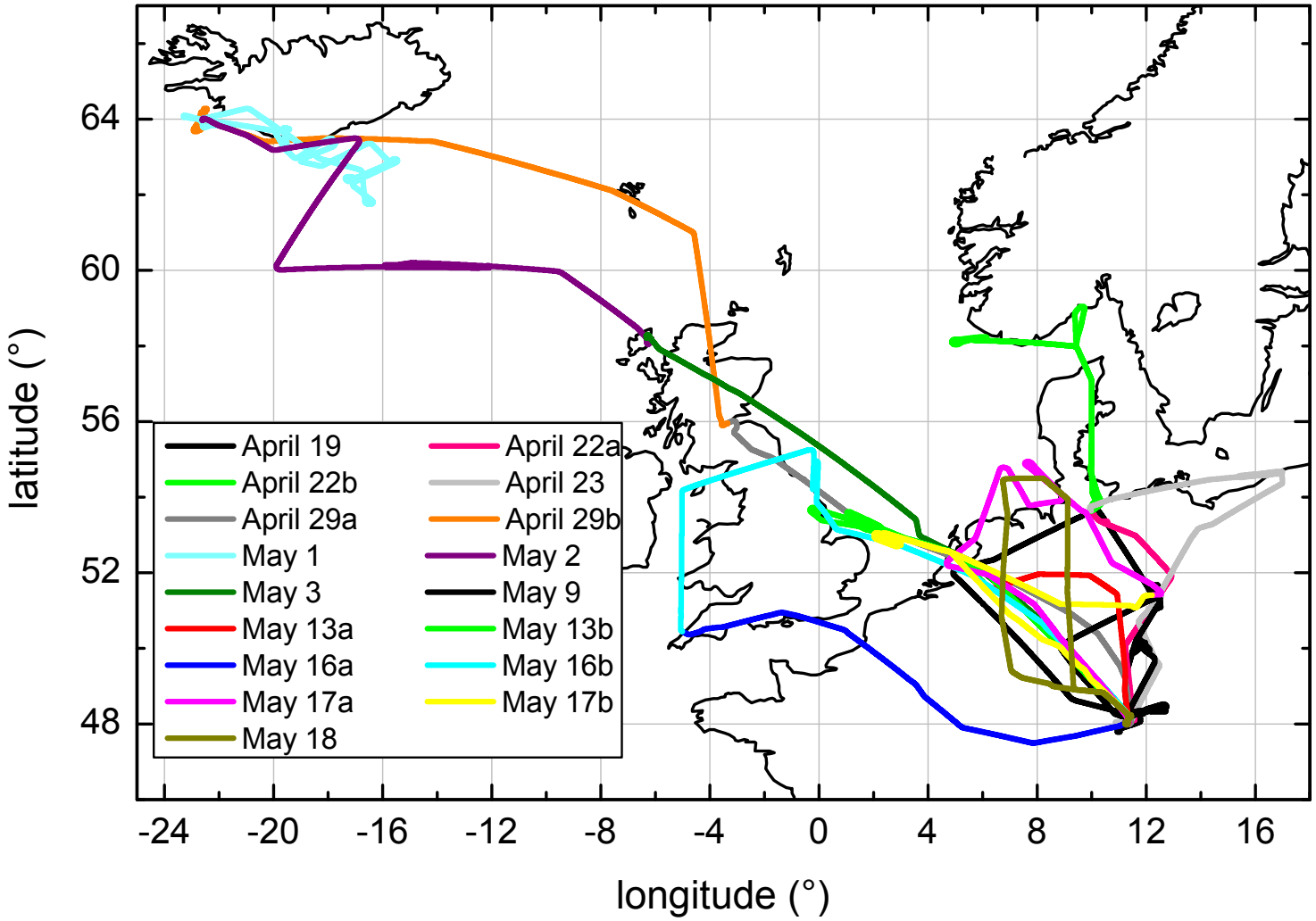
- Closure of airspace justified or exaggerated?
- Quality of forecasts?
- Altitudes of volcanic ash layers? → lidar observations
- Mass concentrations? ← 2 mg/m³ regulation for no-fly-zone
- Aviation conditions near Iceland?

- Particle properties in volcanic ash plumes?
- How to convert particle number concentrations to mass concentration?
- Other plume signatures? SO_2 enhanced?
- Transport of volcanic ash plumes and ageing of particles?

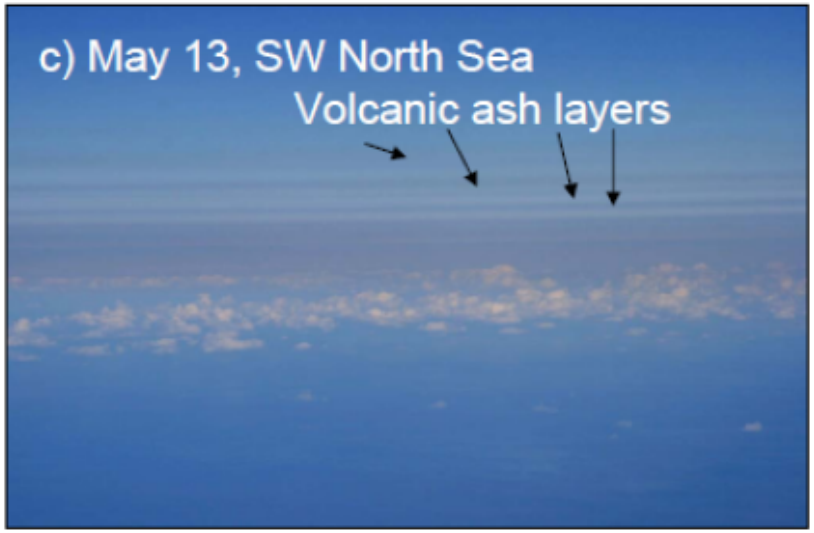
DLR Falcon "emergency" instrumentation for April/May 2010

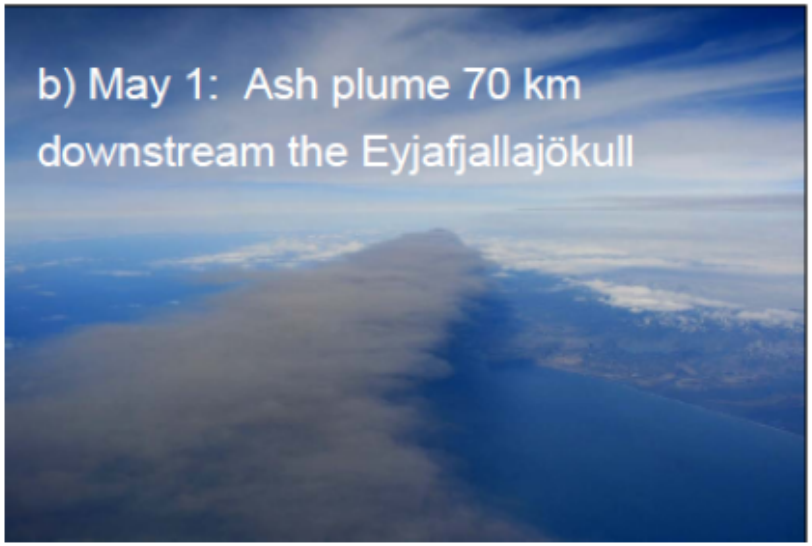


Flight tracks of DLR Falcon
(17 flights, 51 flight hours from April 19 until May 18, 2010)



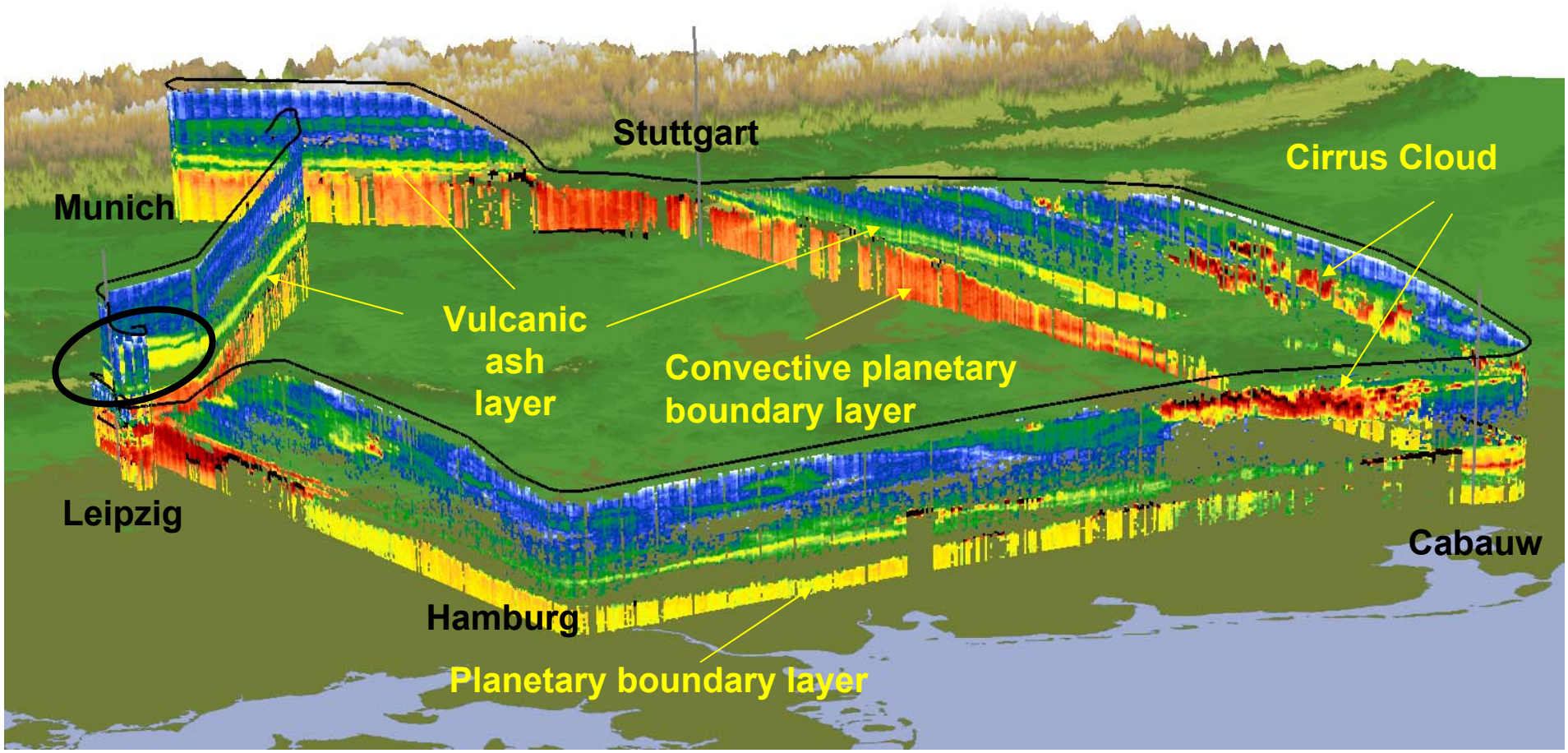
Visual appearance of volcanic ash layers



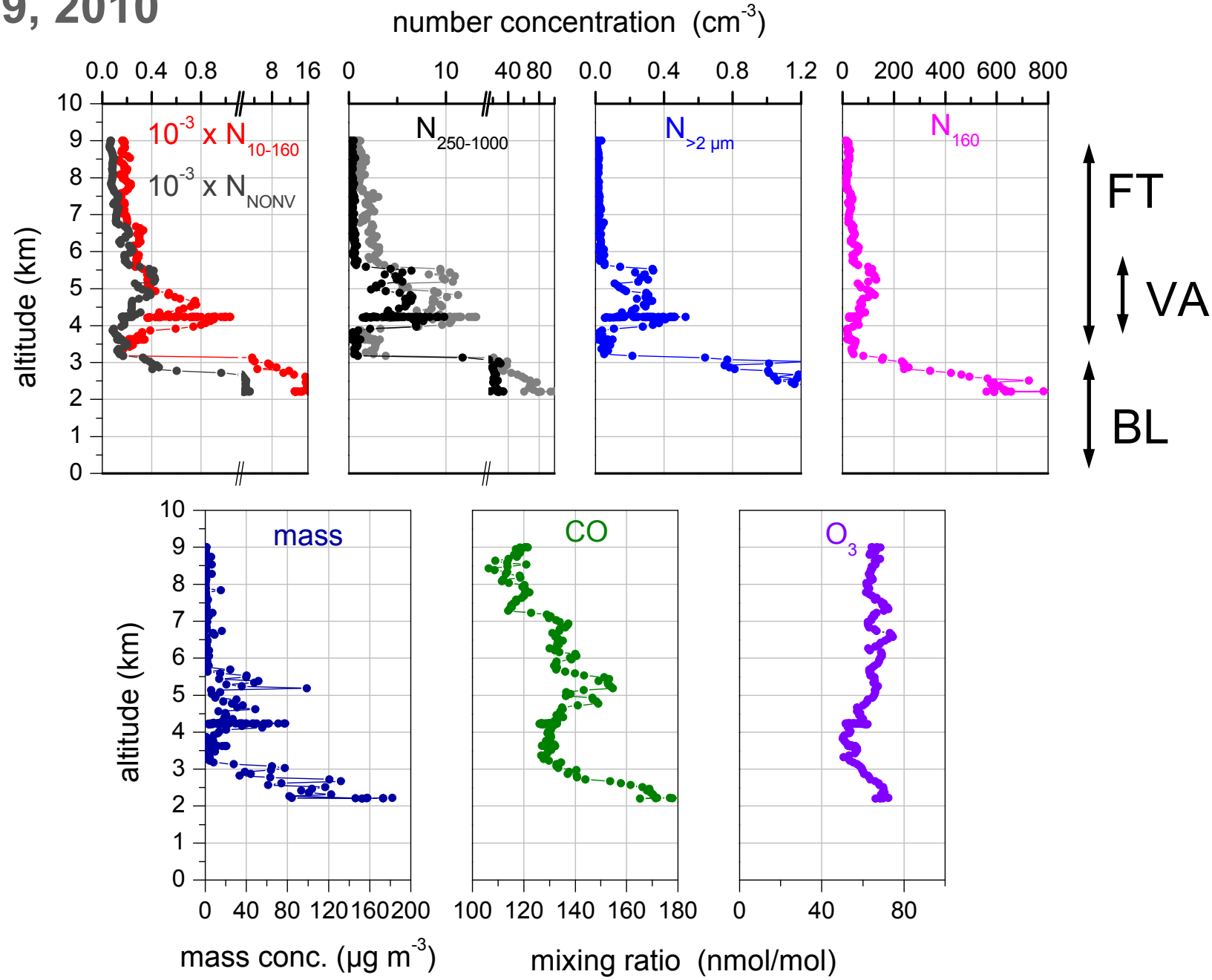


- ash layers visually look like other pollution layers (reducing visibility)
- except very close to the source

April 19, 2010 – airborne lidar as pathfinder

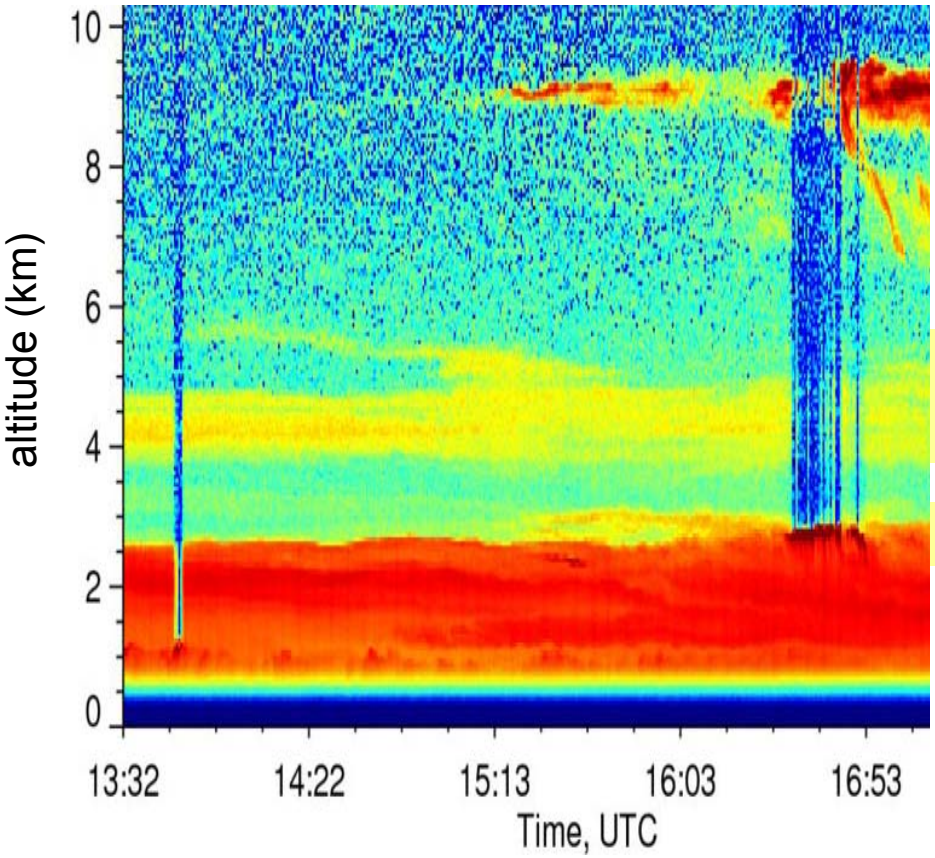


Vertical profiles near Leipzig
April 19, 2010

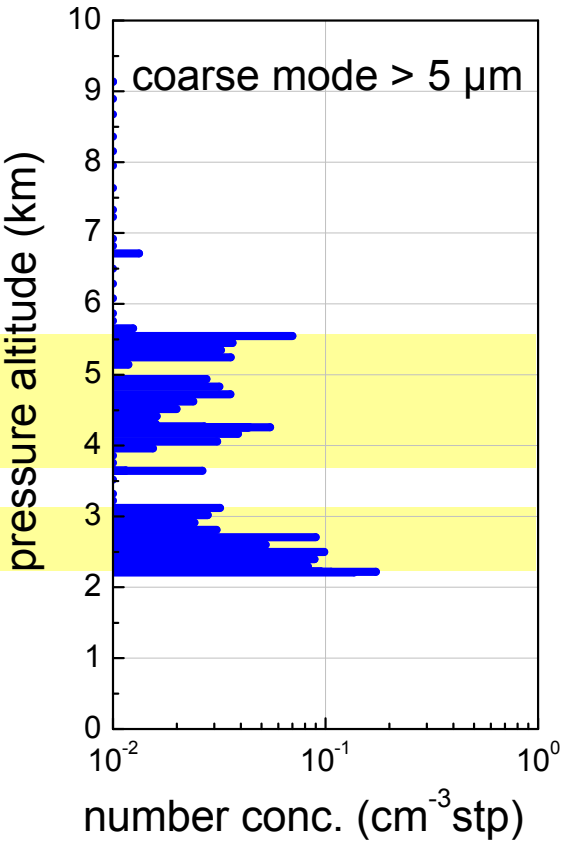


April 19 – Vertical profile measurements over Leipzig

Leipzig lidar

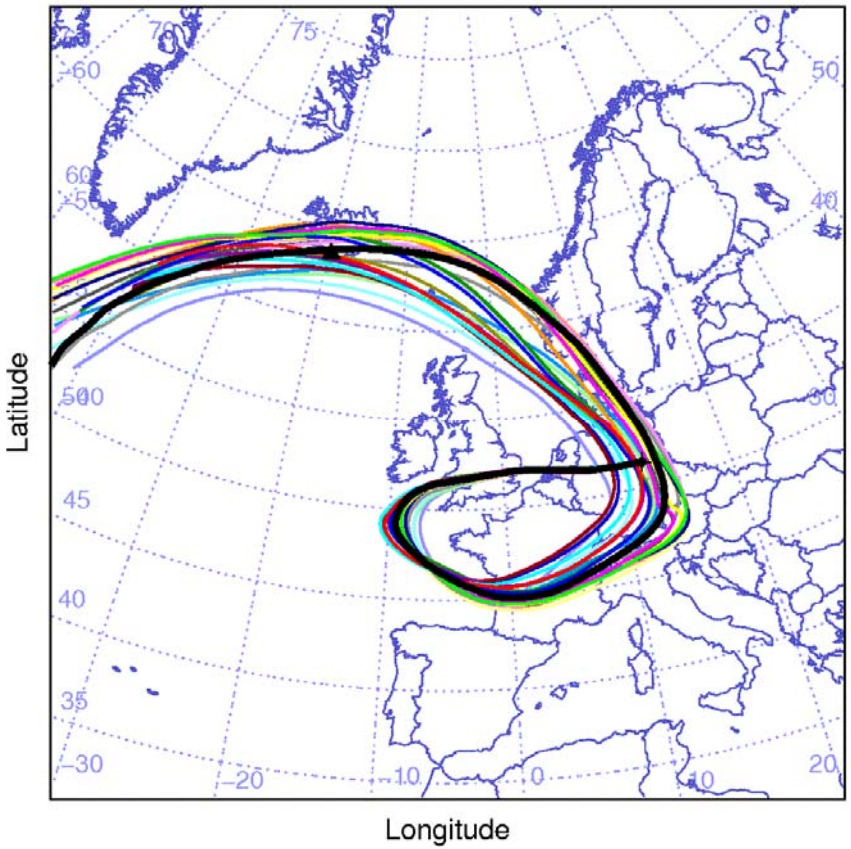


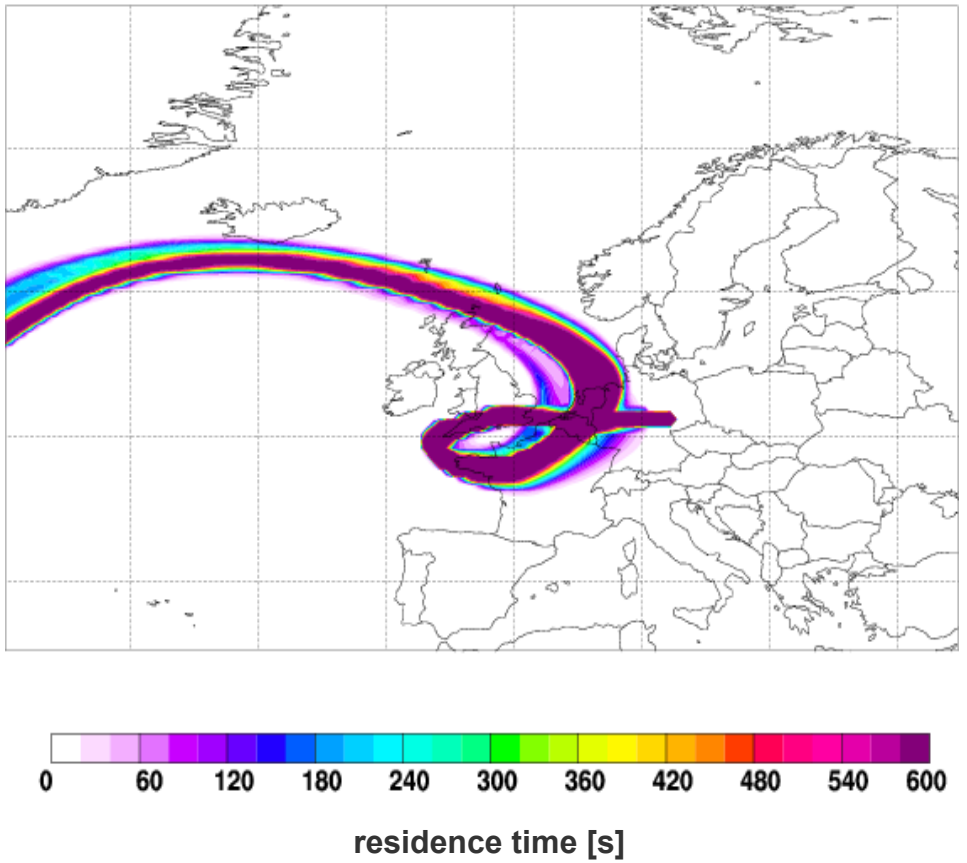
DLR Falcon, 14:50-15:30 UT



IfT Leipzig: A. Ansmann, M. Tesche, P. Seifert
(see also: Ansmann et al., GRL, 2010)

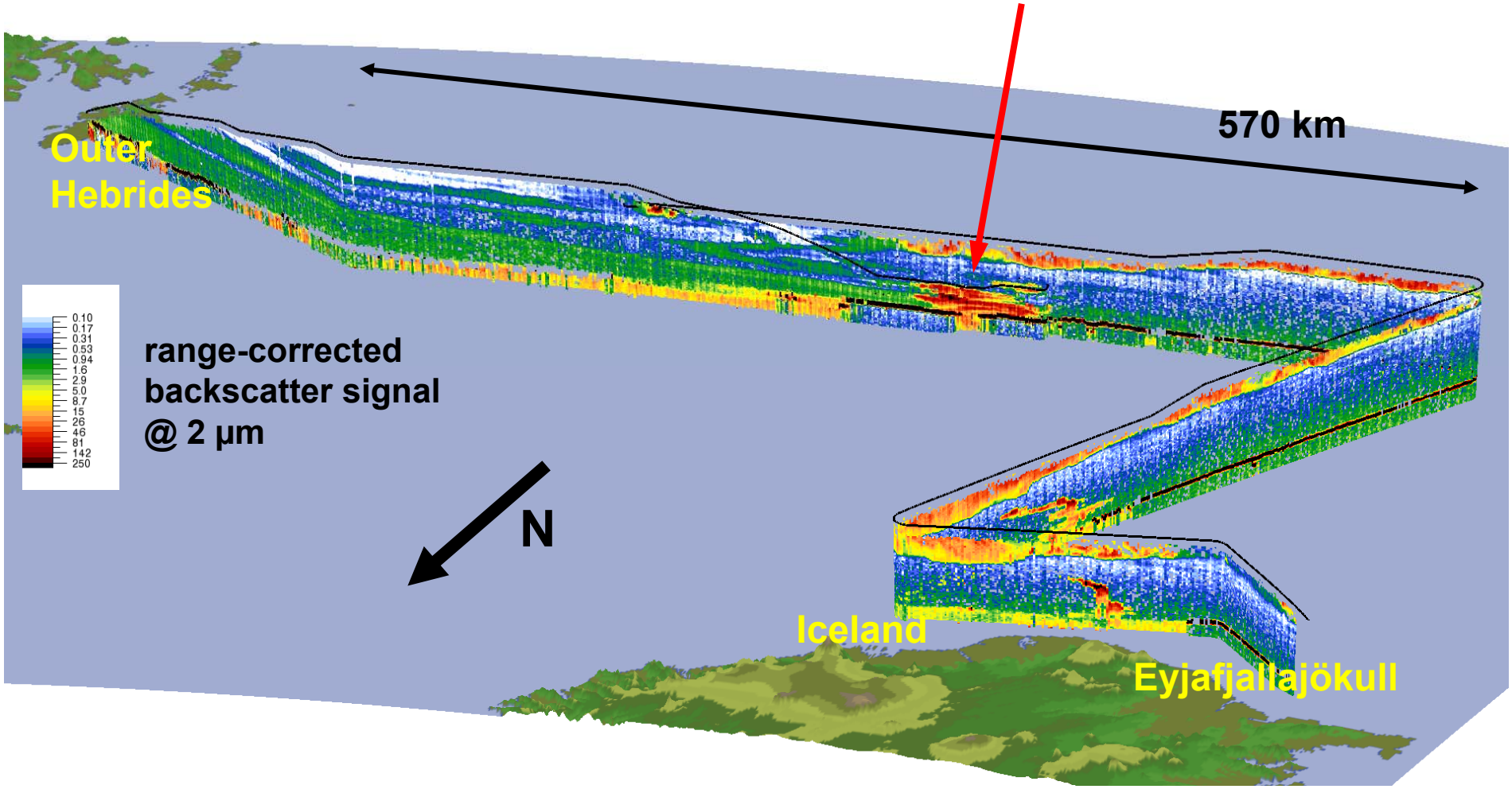
Plume ages April 19: 4-5 days based on backward trajectories



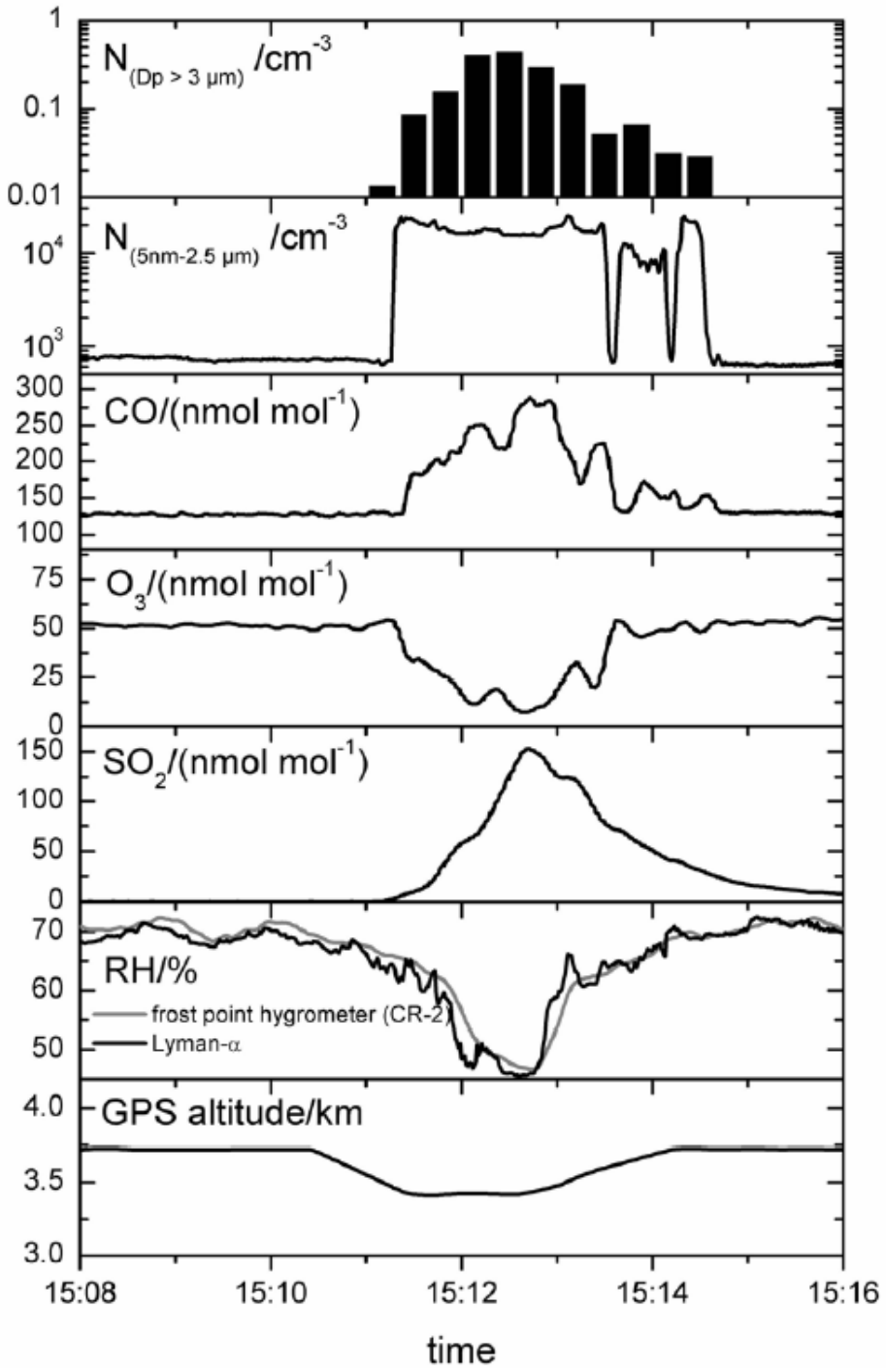


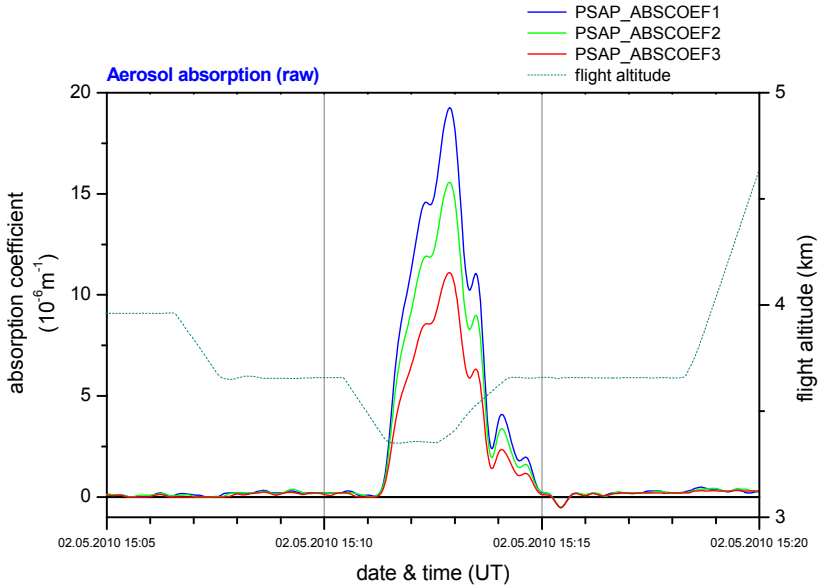
- Alltogether 35 plume entcounters identified in our in situ data set
- Age estimates range from 7 hours (May 2) to 5 days.

May 2, 2010: Highest ash concentration encountered in top of 7 hour old plume sampled over North Atlantic

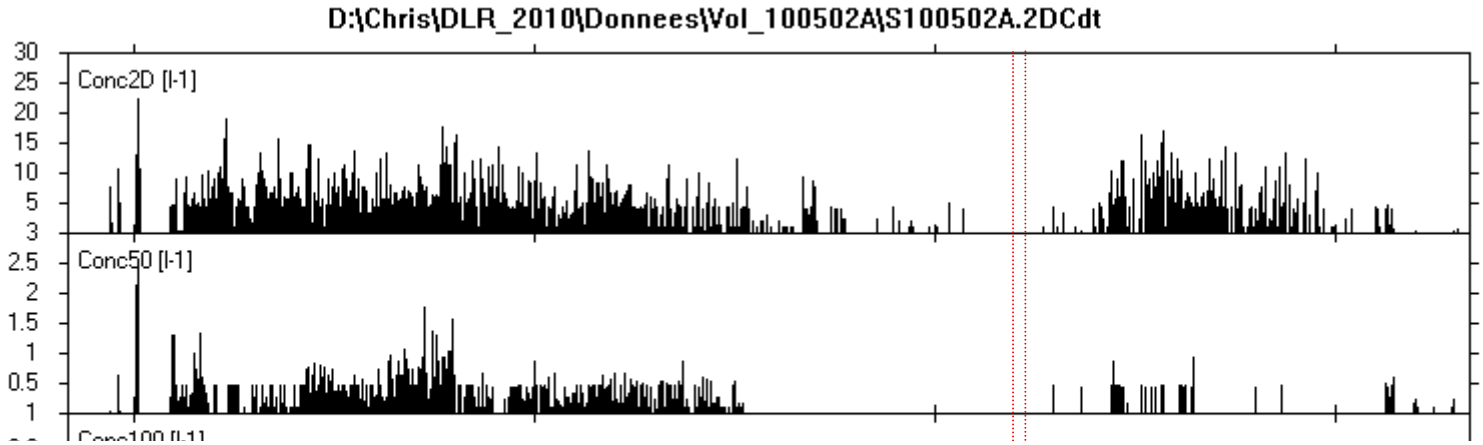


May 2, 2010, plume: Aerosols, SO_2, CO

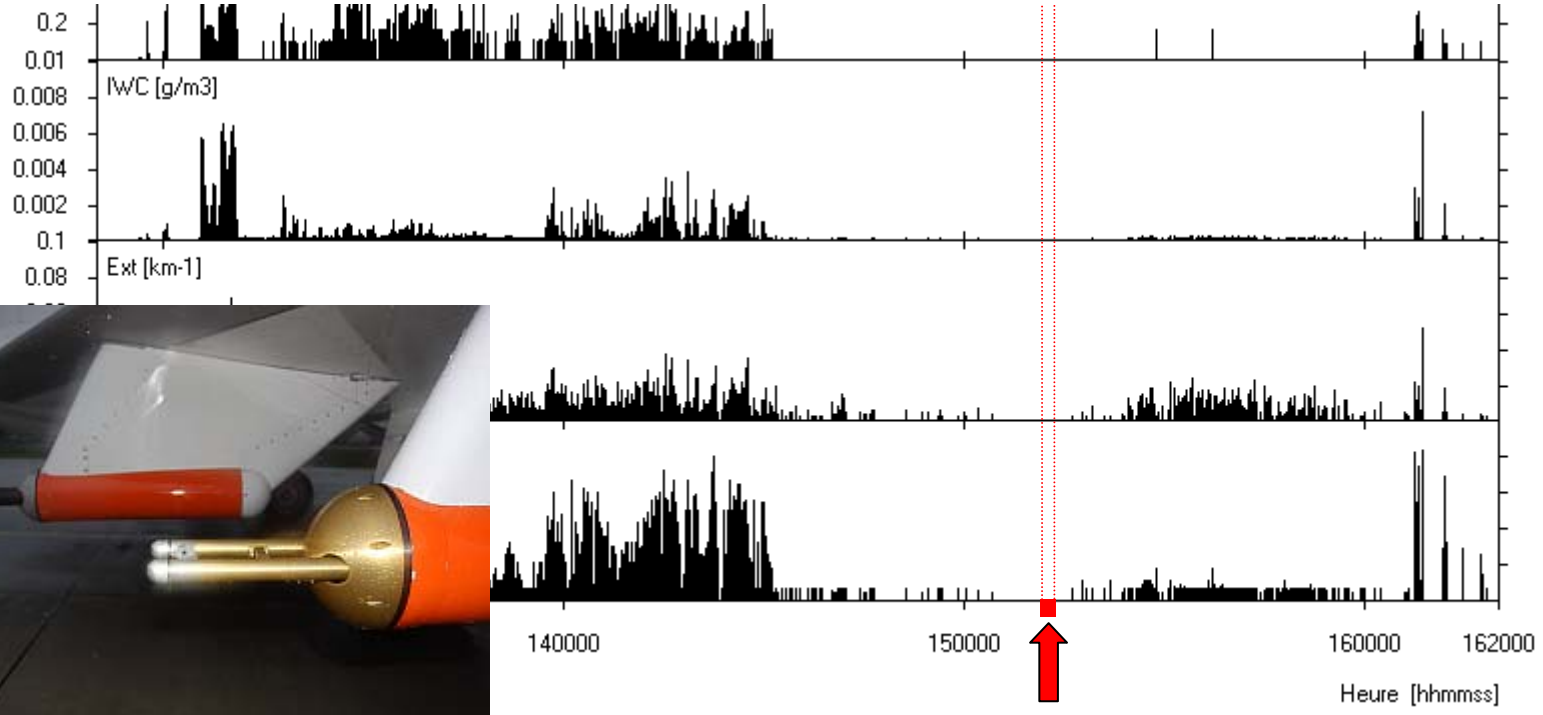




Absorption coefficient
(yet uncorrected for scattering)



➔ **in the volcanic ash layer no particles > 25 µm**



2D-C (Size range 25-800 µm)

J.-F. Gayet & C. Gourbeyre, Clermont-Ferrand

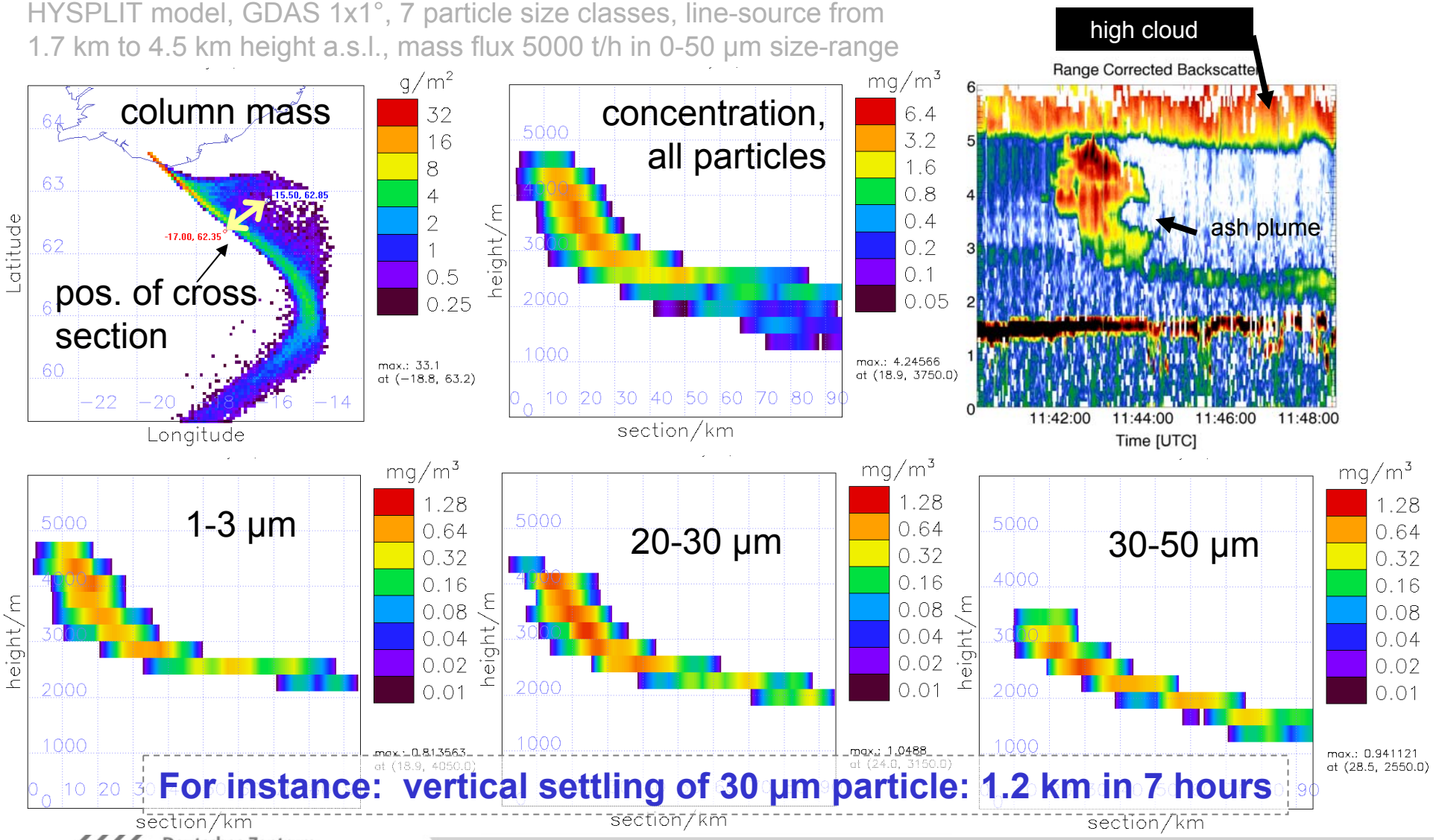
cnrs

Université Blaise Pascal CLERMONT-FERRAND

OPGC Observatoire de Physique du Globe de Clermont-Ferrand

Simulated cross-section of the plume after 7 hours
Faster sedimentation of larger particles

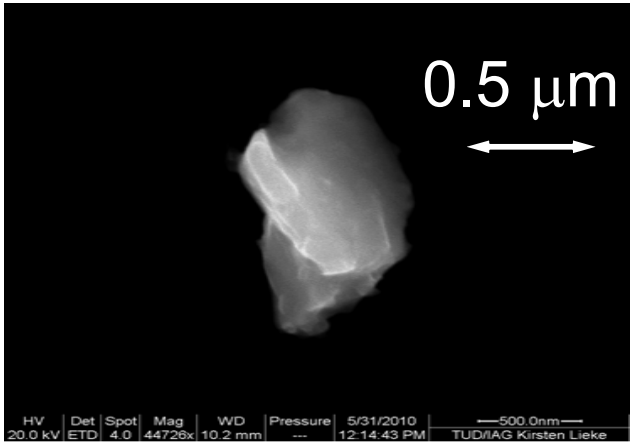
HYSPLIT model, GDAS 1x1°, 7 particle size classes, line-source from 1.7 km to 4.5 km height a.s.l., mass flux 5000 t/h in 0-50 µm size-range

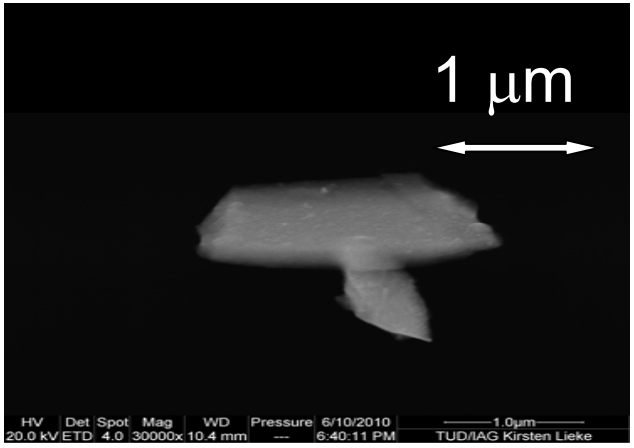


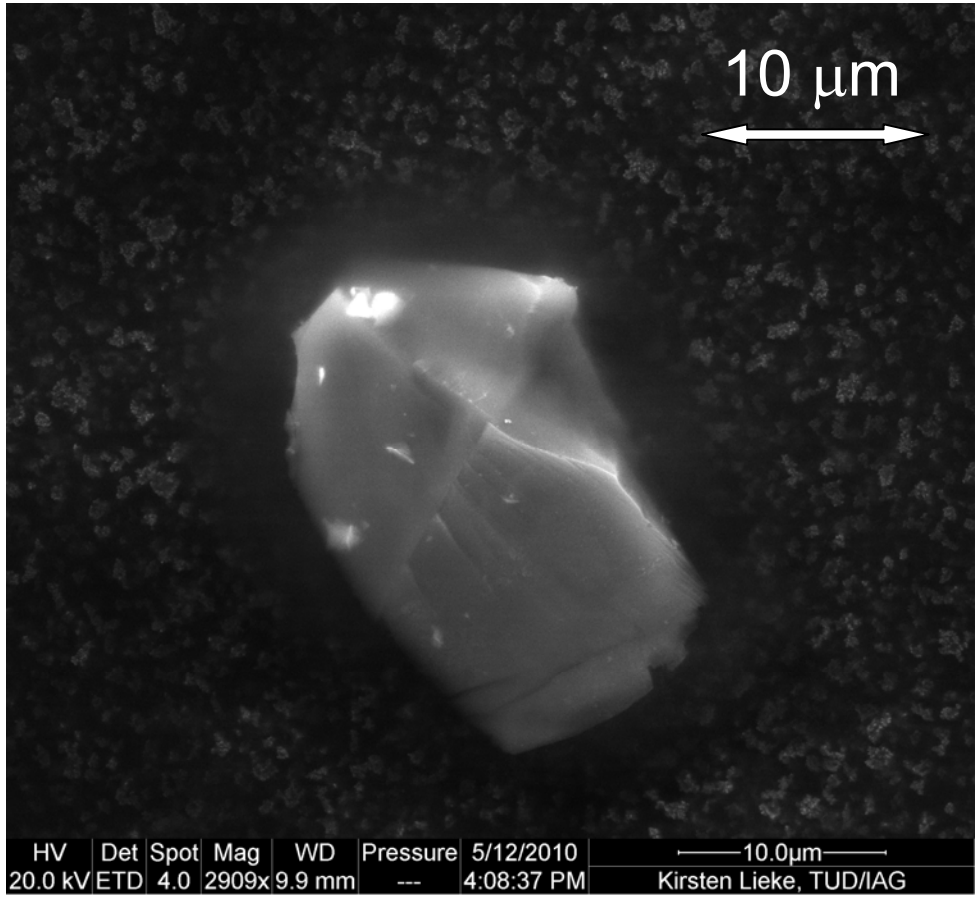
For instance: vertical settling of 30 µm particle: 1.2 km in 7 hours

Results of GPaC and mini-impactor samples for May 2
Largest particle found was 19 µm

from scanning electron microscope with an attached EDX detector



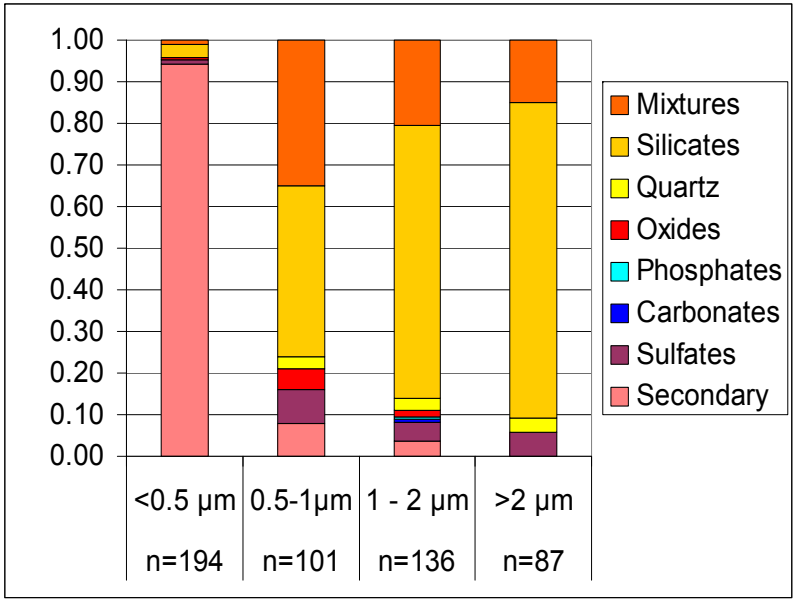


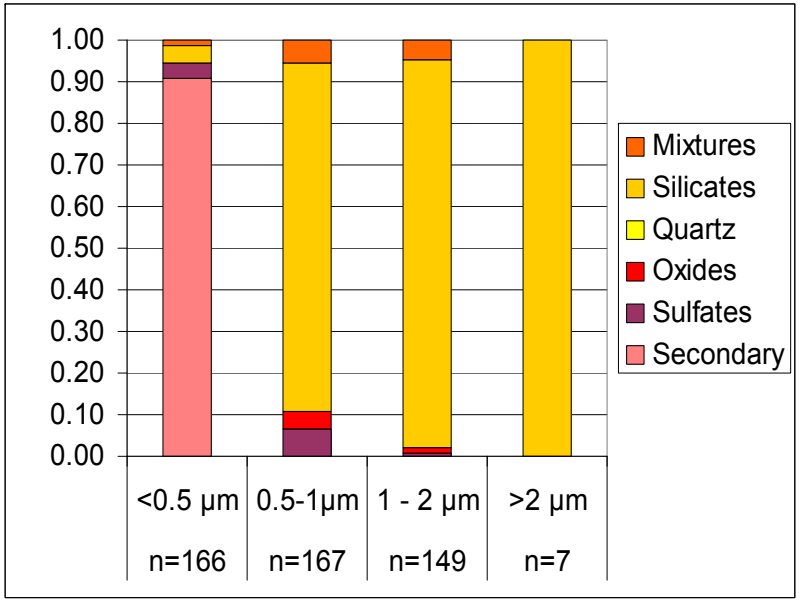


K. Lieke, K. Kandler, M. Ebert, S. Weinbruch

Institut für Angewandte Geowissenschaften, Technische Universität Darmstadt, Germany

Composition, refractive index, aspect ratio and density determined from mini-impactor samples





	May 2, 2010, Atlantic				May 17, 2010, North Sea			
Size/µm	<0.5	0.5 - 1	1 - 2	>2	<0.5	0.5 - 1	1 - 2	>2
Number	194	101	136	87	165	166	149	7
Aspect ratio	1.9	2.2	2	2.1	1.8	2.1	2.1	2.
density	1.8	2.6	2.7	2.7	1.7	2.8	2.7	2.7
m (630 nm)	1.53 +	1.60 +	1.58 +	1.56 +	1.55 +	1.59 +	1.57 +	–
	0.001i	0.004i	0.002i	0.001i	0.001i	0.003i	0.001i	

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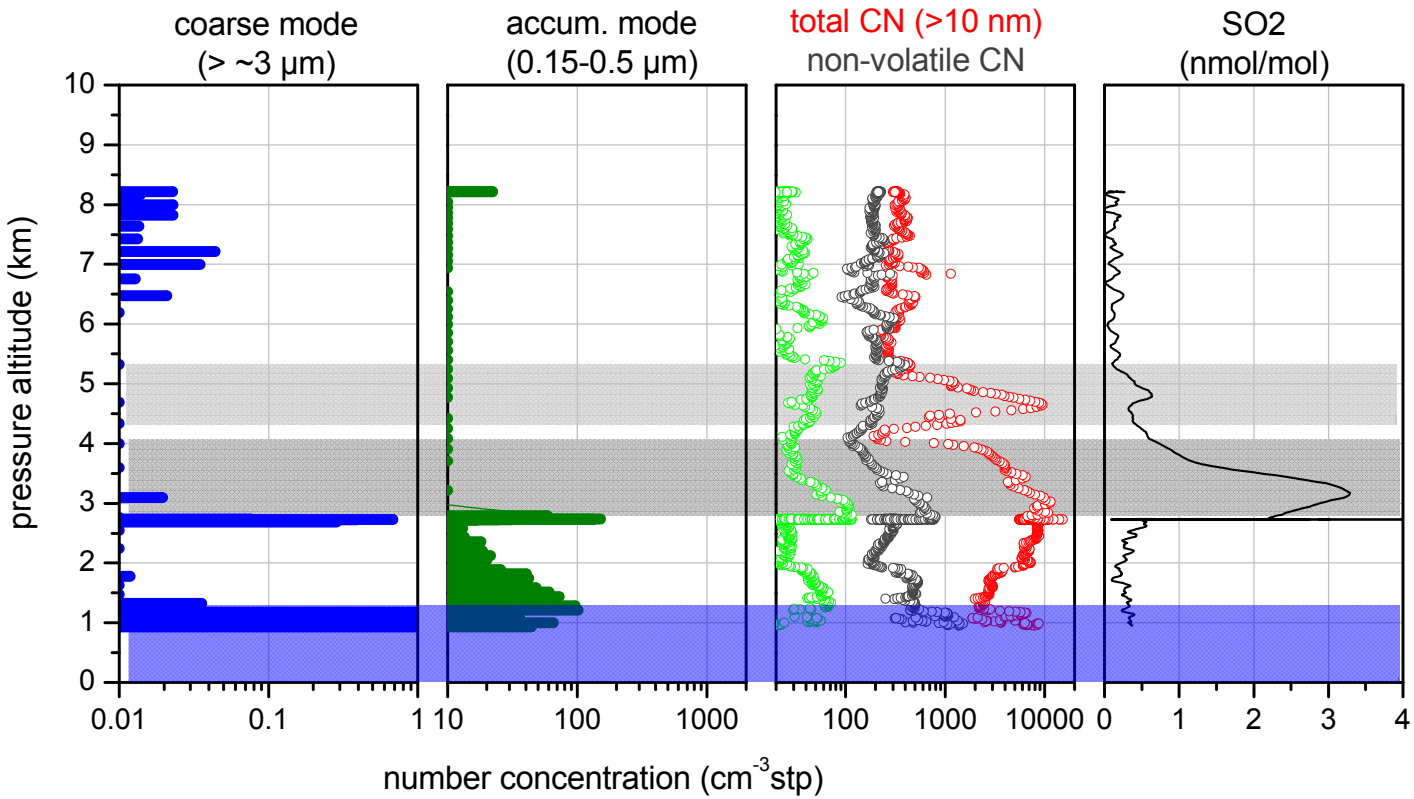
Volcanic ash plume on April 22, over North Sea.
High SO_2, high total CN, but <u>absence</u> of coarse mode particles

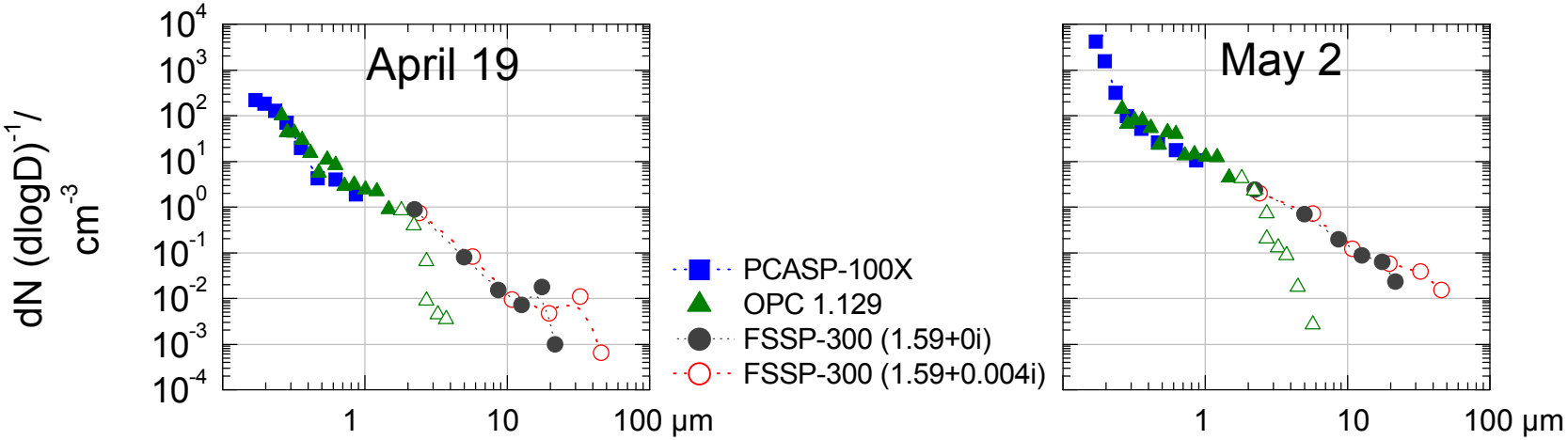
DLR Falcon, flight 100422b, 22-April-2010
"North Sea ascend profile"



➔ previous wash-out? ➔ separation of plumes?

Size distributions from optical aerosol spectrometers

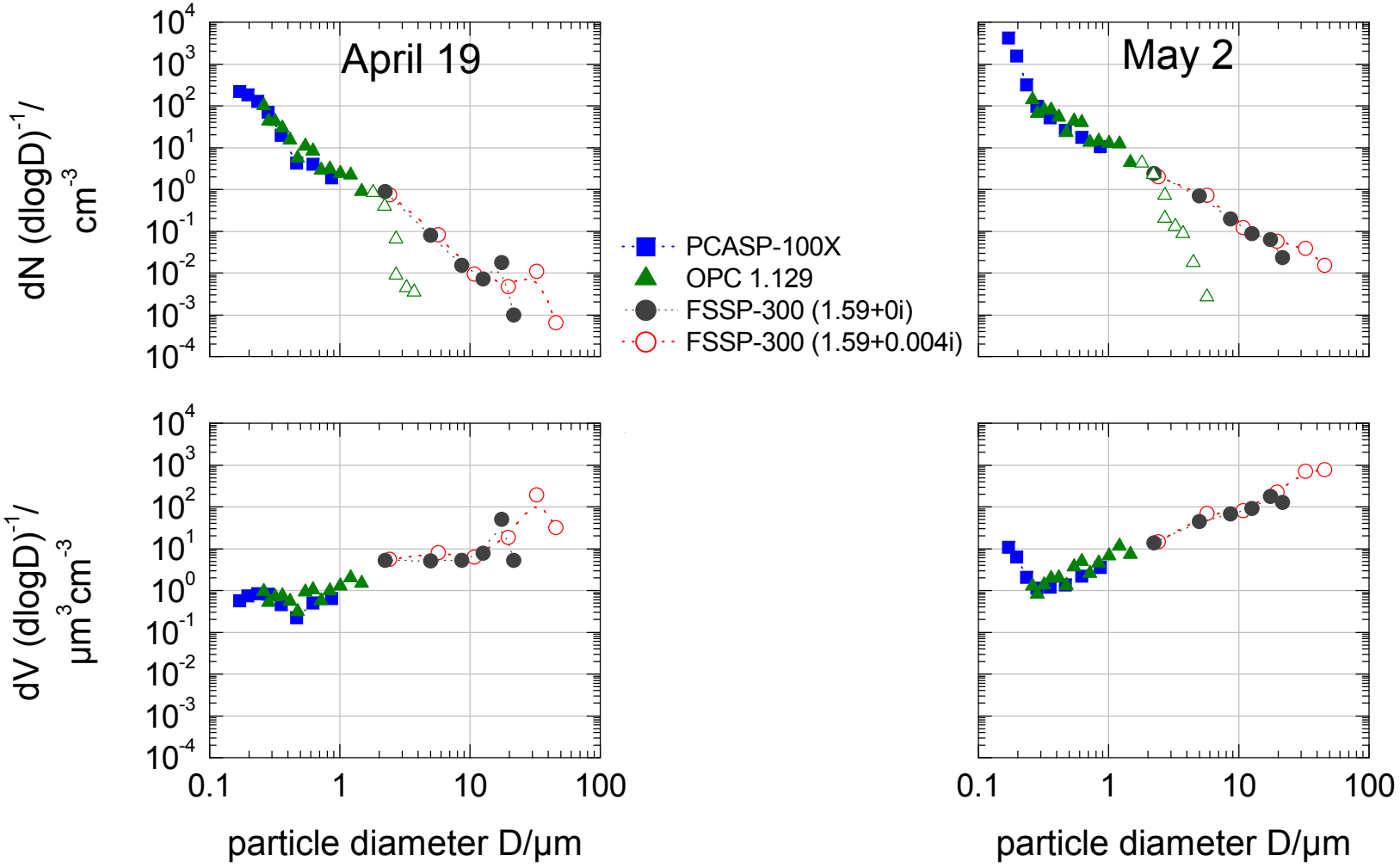
using refractive index 1.59 + 0.0i & 1.59 + 0.004i



- ✈ Good agreement between PCASP and OPC below 2.5 µm
- ✈ OPC in the cabin clearly affected by inlet cut-off above ~2.5 µm
- ✈ FSSP-300 size distribution tails off only very slowly
- ✈ Different refractive index (with/without absorption) changes largest size considerably ➔ will affect total volume/mass
- ✈ Maximum particle diameters of 30-40 µm for absorbing case appear to be rather unrealistic

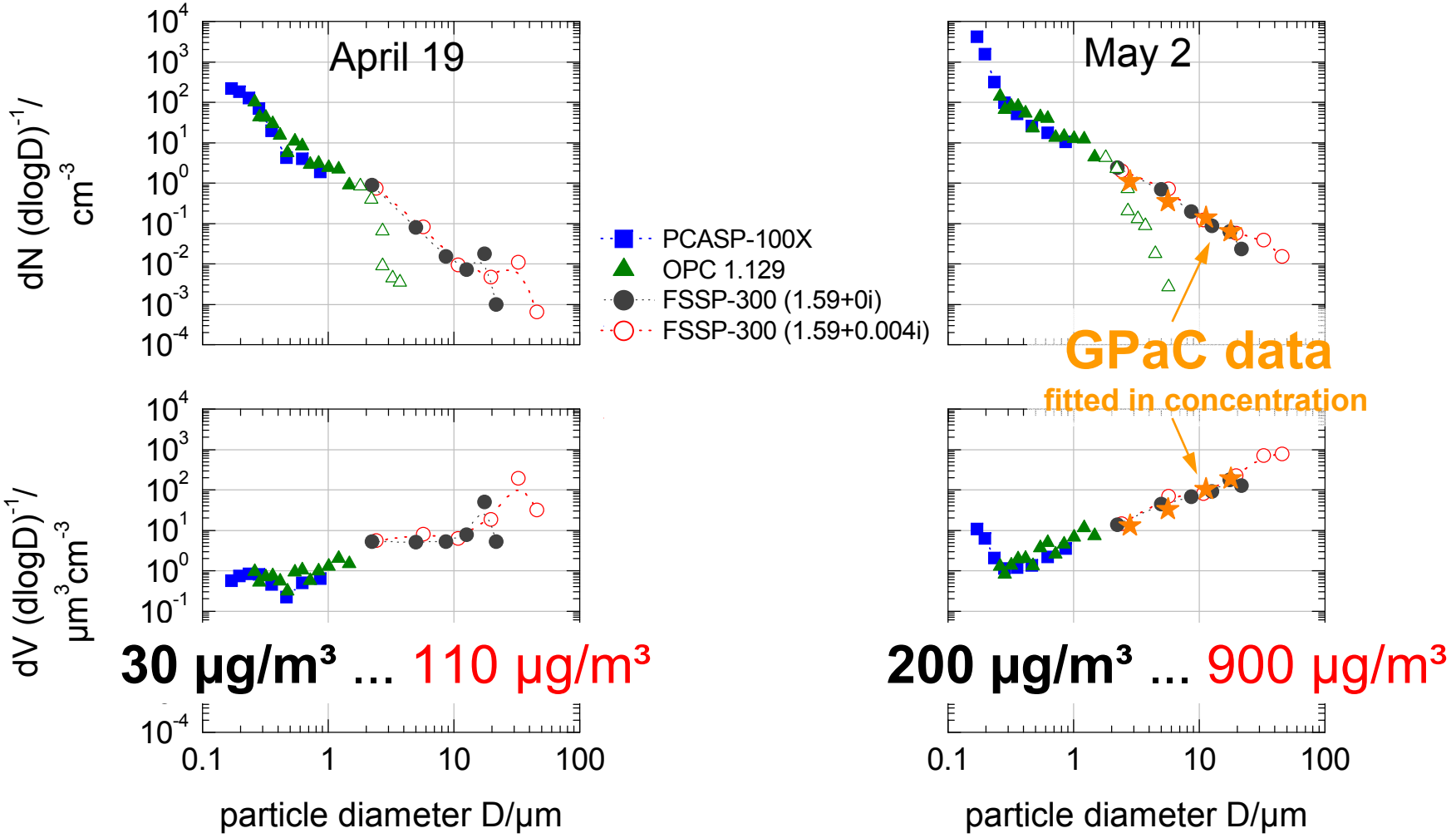
Size distributions from optical aerosol spectrometers

using refractive index 1.59 + 0.0i & 1.59 + 0.004i

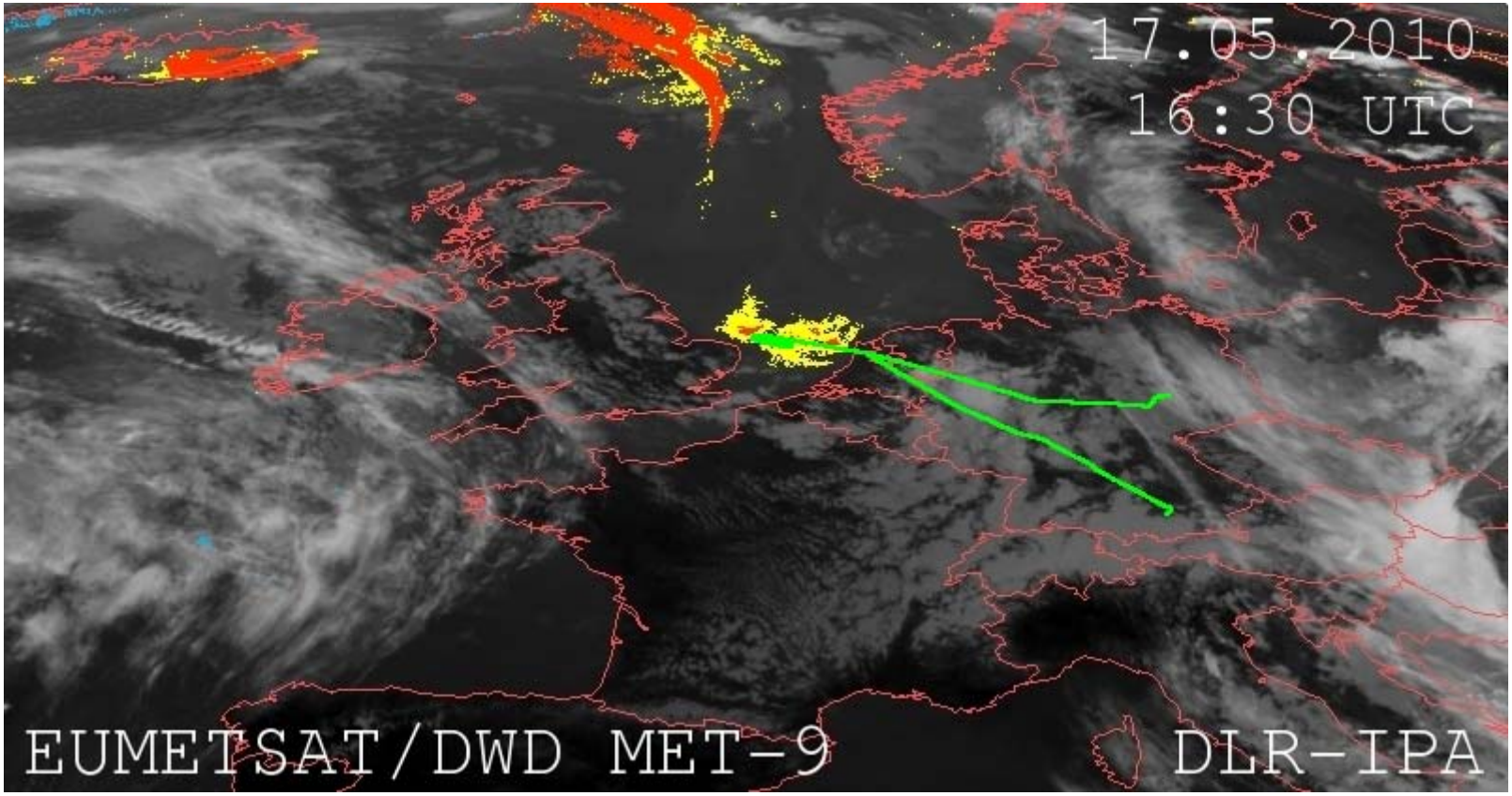


Size distributions from optical aerosol spectrometers

using refractive index 1.59 + 0.0i & 1.59 + 0.004i, density 2.6 g/cm³



May 17, 2010, case: Fairly dense plume over North Sea
clearly seen in MSG ash retrievals, 60 min flight inside this plume



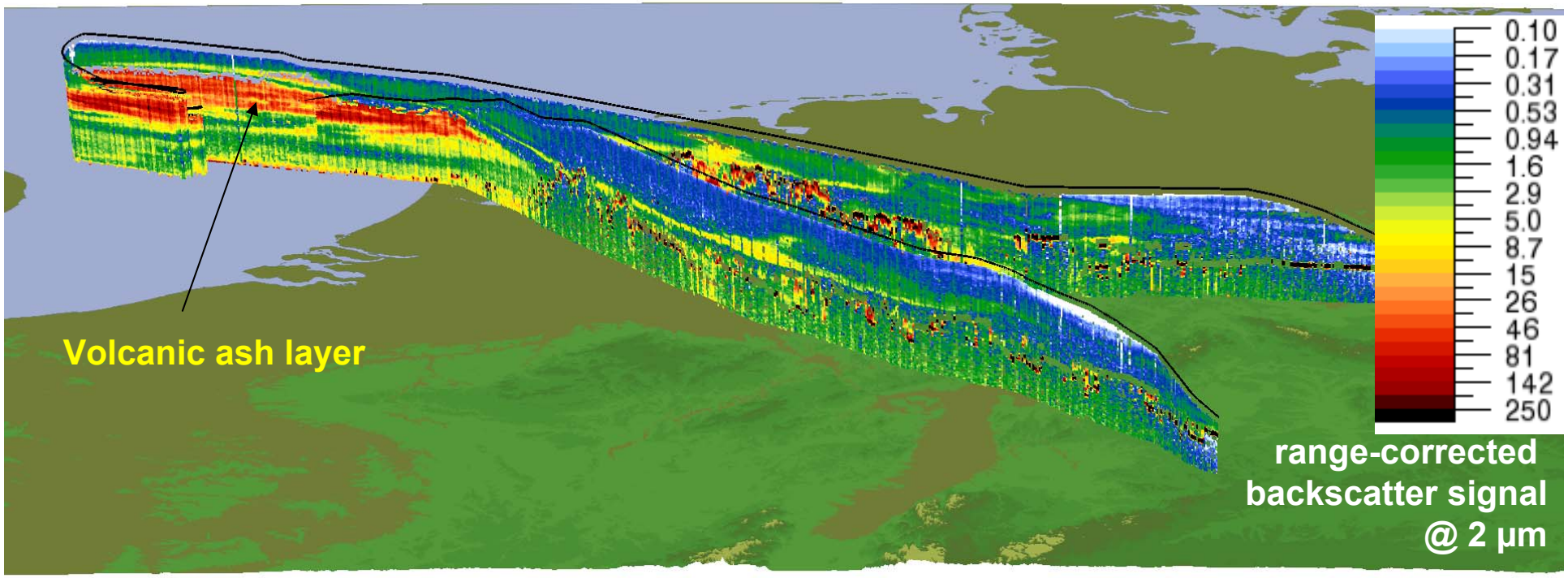
yellow = ash retrieval

red = ash + SO2 retrieval

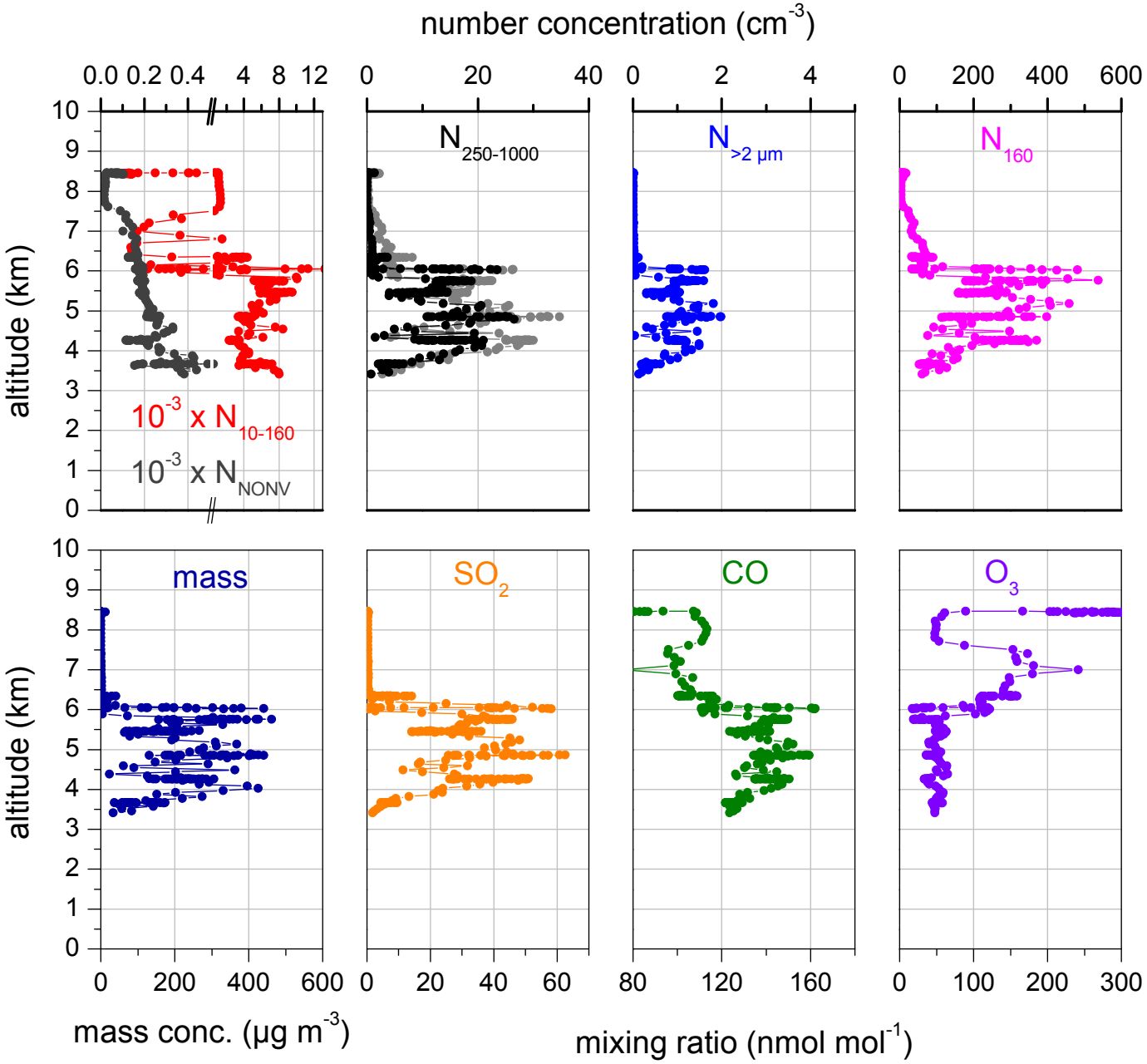
green = Falcon flight track

May 17, 2010, case: Fairly dense plume over North Sea

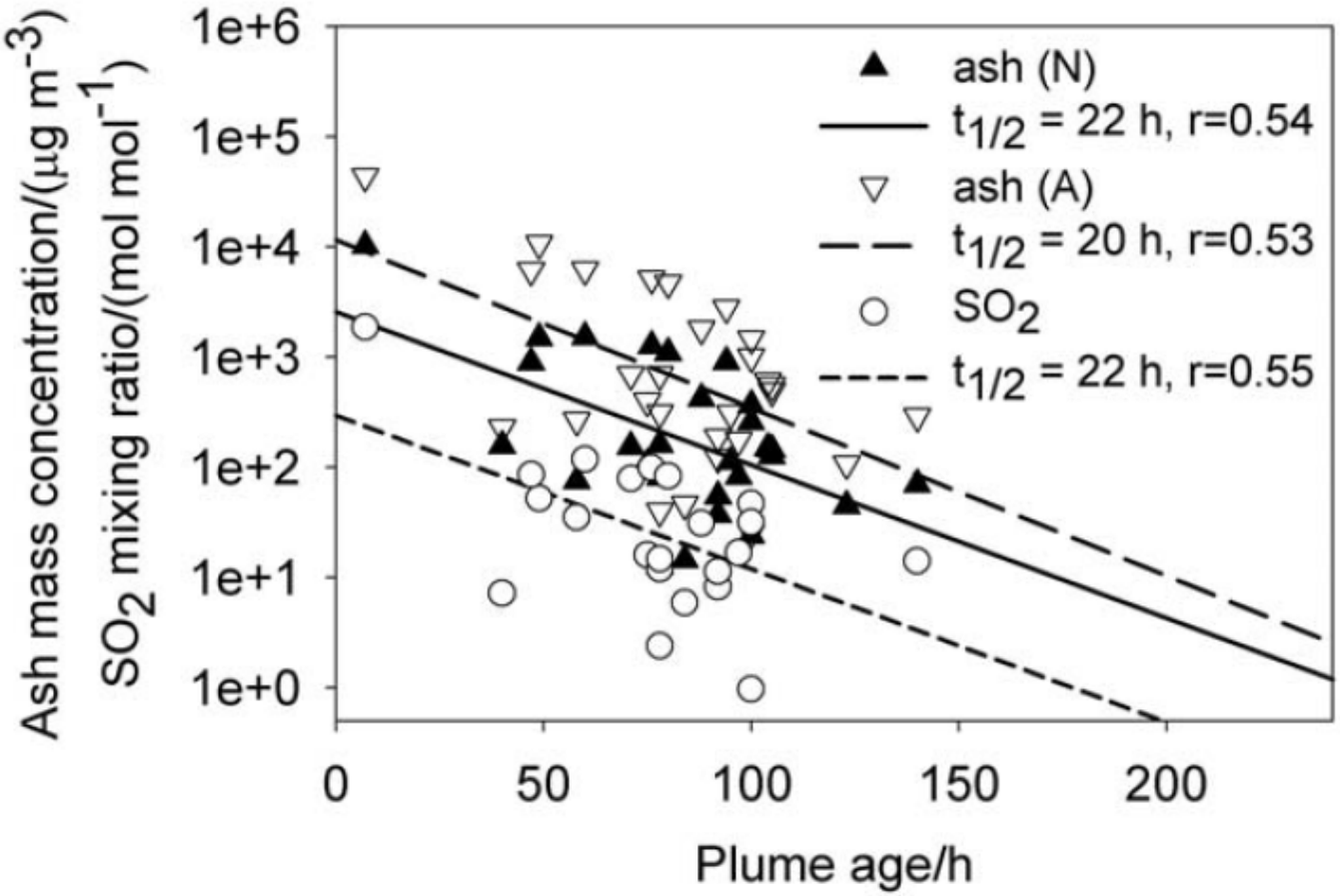
60 min flight inside this plume



May 17, 2010, case: Plume thickness 3 km



Volcanic ash & SO_2 concentrations with plume age: Overall similar dilution, but high variability



Summary of UK plume flying

Date	Dornier 228	BAe-146	146 Instrumentation	228 Instrumentation
20100416				CPC + SO2+PCASP
20100418				CPC + SO2 + Grimm
20100419				CDP+SO2+Grimm+PCASP+CPC
20100420			Lidar/Aerosol/Cloud phys	Grimm+CPC
20100421			Lidar/Aerosol/Cloud phys	PCASP+CDP+SO2+Grimm+CPC
20100422			Lidar/Aerosol/Cloud phys	Grimm+CPC
20100504			Lidar/Aerosol/Cloud phys	
20100505			Lidar/Aerosol/Cloud phys	
20100514			Lidar/Aerosol/Cloud phys	
20100516			Lidar/Aerosol/Cloud phys	
20100517			Lidar/Aerosol/Cloud phys	
20100518			Lidar/Aerosol/Cloud phys	

Main conclusions on volcanic ash particle properties

- distinct enhancements of SO_2, and aerosol particles in all size ranges: Total CN (>10 nm), accumulation mode particles and coarse mode particles, mostly co-located (but few cases with plume separation?)
- Layer thicknesses 0.2–3 km. Altitude range 2.5–7 km (plus BL?)
- coarse mode particles even up to 10-20 µm were present in volcanic ash layers
- no particles below 10 nm → ultrafine particle formation and growth occurred within hours from emission
- mass concentration is not a direct measurement. Estimate is quite uncertain (factor of 4) at present mainly because:
  a) total volume is entirely dominated by large supermicron particles (measured only by one single instrument, here FSSP-300)
  b) uncertainties in refractive index (absorbing component) which is not yet known with high accuracy – and is likely to be size dependent (chemical composition is size dependent)
- mass concentration range encountered by Falcon: 5 to 200 µg/m³ plume average, up to 500 µg/m³ in peaks
- Paper by Schumann et al. submitted to ACPD

Funding of flights by:
- ✈ Deutscher Wetterdienst (DWD, German Weather Service)
- ✈ Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS)

Thank you!

And please, Iceland, no more volcanic eruptions this year!